Pastureland degradation and poverty within herder communities in Mongolia: data analysis and game estimation

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Abstract

Since the beginning of the country's transition to a market economy, herders in Mongolia have encountered enormous challenges. Degradation of pastureland resulting from overgrazing seriously jeopardizes the vulnerable livelihoods of herder household economies. An analysis of the grazing strategies used by herders in the Ugtaal district in the Tov province (North of the capital) and the Gurvansaikhan district in the Dundgovi province (south of the capital) is the focus of this study.

Analysis of collected primary data (using a Principle Component Analysis) revealed that herders in Ugtaal rank security before environmental quality in their grazing strategies, while herders in Gurvansaikhan rank environmental quality first. A regression analysis indicated that richer herders care more for the environment than poorer herders in Ugtaal. The game estimation shows that herders in Ugtaal face a reverse assurance game in choosing the growth in herd size. Hence, herd maximising behaviour leads to the highest payoff, while a second equilibrium exists where herders keep their herds constant. The herders in Gurvansaikhan also face a reverse assurance game in choosing the growth in herd size. The conclusion of this game is the same as for the game in Ugtaal. Institutional changes could alter herders' behaviour, but this would come at the cost of lowering their income by about 30% in Gurvansaikhan, and by as much as 60% in Ugtaal.

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1. Introduction

Since the beginning of the country's transition to a market economy, herders in Mongolia have encountered enormous challenges. Degradation of pastureland resulting from overgrazing seriously jeopardizes the vulnerable livelihoods of herder household economies.

After the collapse of communist rule in Mongolia in 1991, the demise of the livestock collectives resulted in individual (household-based) livestock ownership, and an unclear range of management institutions. Between 1991 and 1998, the livestock enterprise rapidly expanded. This was partly due to relatively good weather conditions, and partly a result of the de-industrialisation of the urban economy, which led to many people entering the livestock economy. In 1990, Mongolia had 25.9 million domesticated animals. In 1998, this had grown to 32.9 million, an increase of 27%. The increase was not a result of a growing number of sheep; indeed, the number of sheep even decreased slightly, from 15.1 million to 14.7 million. In addition, the number of camels decreased from 0.5 million to 0.4 million. The growth was instead due to increasing numbers of horses (from 2.3 million to 3.0 million), cattle and yaks (from 2.8 million to 3.7 million), and goats (from 5.1 million to 11.1 million). The rapid growth of the number of goats was a result of a strong demand for goats' hair, also known as cashmere (NSOM 2001).

Between 1990 and 1998, the weather conditions were favourable. Compared to the 1980s, rainfall was higher and the winters less severe (Batjargal et al, 2000). The carrying capacity of the Mongolian grazing lands improved, and generally accommodated the growing livestock population. However, i) changes in livestock mobility, ii) a new range of management styles and iii) unclear grazing institutions under privatised livestock management regimes, started to create carrying capacity tensions in some areas. Where water wells were no longer maintained, some grazing areas were abandoned, resulting in concentrated grazing in other areas[2].

Between 1999 and 2002, winter conditions deteriorated and spring/summer rainfall also declined. The *dzuds*, as these severe winters are known in Mongolia, were disastrous for both Mongolian livestock and for the expanded herder community. It was estimated that 12 million animals died nation-wide, and out of an estimated 190,000 herding households (in 1998), 11,000 families lost all their animals (Danker, 2004, p. 26). In December 2002, the total number of animals had gone down to only 24 million, back to the level of the late 1980s. Compared to 1998, losses were most severe among horses (-64%) and cattle (-49%), and least severe among goats (only -18%). These figures are presented in Table 1.

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[2] According to CPR (2003), out of 41,600 wells operational in 1990, only 30,900 were still operational in 2000.

Table 1 Livestock numbers in Mongolia, 1990, 1998 and 2002.

	1990	1998	2002	% change over 1990-1998	% change over 1998-2002
Horses	2.3	3.0	1.1	33%	-64%
Cattle/Yak	2.9	3.7	1.9	30%	-49%
Camels	0.5	0.4	0.3	-26%	-35%
Sheep	15.1	14.7	10.6	-3%	-28%
Goats	5.1	11.1	9.1	117%	-18%
Total	55.3	69.9	39.0	26%	-44%

Note: Total is expressed in sheep units (SU): 1 sheep = 1 SU, 1 horse = 7 SU, 1 cattle/yak = 6 SU, 1 camel = 5 SU, 1 goats = 0.9 SU.

The Mongolian Government has shifted in its policy direction towards more productivity-oriented herding strategies. However, it is likely to take substantial time and effort before Mongolian herders adopt these new approaches. Traditionally, herders believe that good years follow bad years, and former losses will usually be recovered. This mentality persists today and appears to be a major psychological barrier preventing herders from preparing better for the (often-severe) winter season. It also motivates herd maximising behaviour.

Through game analysis, this paper aims to highlight the unsustainable nature of herder behaviour. The type of game herders face when competing for grazing pastures will be determined by looking at actual herders' behaviour. A further objective of this paper is to identify the main dimensions of herder behavior, by undertaking a Principal Component Analysis.

The hypotheses that guide the study are:

- The poorer the herders, the worse the quality of their pastureland;
- The poorer the herders, the greater the willingness to maximise animal numbers.;
- Maximising animal numbers is optimal behaviour for herders;
- There are viable ways to change herders' behaviour towards socially optimal animal numbers;
- Herder behaviour which maximises animal numbers causes a long-term degradation of ranges, which increases poverty.

To test these hypotheses, we gathered (empirical) information on three key sets of variables, namely (1) herder income as a proxy for *poverty*, (2) change in animal numbers as a proxy for herder *behaviour*, and (3) herder perception of the environment as a proxy for *environmental degradation*.

The outline of this paper is as follows: Section 2 starts with a presentation of the grazing situation in Mongolia. It highlights specific details of the two selected case study regions, Ugtaal and Gurvansaikhan, and discusses the data collected from herders in these regions. The collected data is analysed in Section 3, by undertaking a Principle Component Analysis on the perception herders have of their environment. Additionally, a multiple regression analysis was undertaken to verify, for instance, whether there is a link between poverty and herd size and/or perception of the environment. Section 4 gives the (technical) description of the game estimation in which herders compete for the use of pastureland, and outlines the results of the analysis 4. In Section 5 the study's conclusions are drawn.

2. Description of the field setting

2.1 A specific look at two research areas: Ugtaal and Gurvansaikhan

Two areas were studied. The first area, Ugtaal *sum* (district) in the Tov *aimag* (province), is in the north, in part of what is called the 'forest steppe'. This area has more rainfall and more severe winter conditions. The second area, Gurvansaikhan *sum* in Dundgovi *aimag,* is in the South, close to the Gobi desert. This area has less rainfall and less severe winter conditions.

These two districts have been selected using the following criteria:

- They have different levels of pasture degradation;
- They are in different ecological regions, with varying ecological conditions and land use patterns;
- They vary in terms of how they were impacted by the 1999-2001 *dzuds*.

Ugtaal *sum*, Tov *aimag*

The Ugtaal *sum* is located in Mongolia's steppe region and was created in 1924. The *sum* centre is closer to the capital (at 155 km distance) than to its own *aimag* centre (at 177 km distance). It covers a land area of 154.8 thousand ha, of which 110.7 thousand ha is pasture, 15.1 thousand ha is arable land and 1.2 thousand ha consists of haymaking areas. It also has 8.3 thousand ha of forest. According to the latest sum (district) statistics, 23.0 thousand ha of pastures have been degraded.

The *sum*'s population was at 2816 as of January 2004, with total of 715 families. 74.8 per cent of families (households with animals) own less than 200 animals. There are 270 families with up to 50 animals per family, including non-herder families (Table 2). From 2002 to 2003, the population and the number of livestock decreased by 9.3 percent and 7.0 percent respectively. The number of households with more than 200 animals decreased by 24 percent, while the number of households with up to 200 animals decreased by 7.7 percent.

The decreasing number of households is primarily explained by outward migration from Ugtaal to other *sum*s. Local people explained that Ugtaal *sum* is not a final destination for migrating households from the western provinces. Those migrating from the western provinces may stay in Ugtaal for a few years and then migrate to the other places. For this reason, 60 households and 340 people migrated on to the other places in 2003.

According to annual livestock census statistics, the living standards of herding households in Ugtaal *sum* are decreasing (Table 2).

Table 2 The household's grouping by number of animals, Ugtaal sum.

Indicators	Years				
	1997	2000	2001	2002	2003
Population	4170	3389	2974	3103	2816
Number of households	n.a.	843	706	775	715
Of which households with animal herds including herders households	794	656	557	562	508
Of which by percentage:					
Up to 10 heads	13.9%	10.1%	11.8%	14.1%	15.6%
11-30 heads	26.2%	16.5%	16.7%	15.8%	22.6%
31-50 heads	15.5%	14.8%	17.4%	17.3%	15.0%
51-100 heads	23.0%	25.6%	23.3%	24.0%	23.0%
101-200 heads	15.2%	16.9%	18.1%	17.3%	14.2%
201-500 heads	5.5%	14.5%	11.3%	10.7%	8.9%
501-999 heads	0.4%	1.5%	1.1%	0.7%	0.6%
1000-1499 heads	0.3%	0.2%	0.2%	0.2%	0.2%
Above 1500 heads	0%	0%	0%	0%	0%

Source: *Sum*'s livestock census data, 2003. n.a. means not available.

The main economic activity is livestock herding and crop farming. The *sum* animals were severely affected by the *dzud* impacts in 2001-2002. In 2000 the number of livestock reached its maximum level of 152 thousand sheep units. At the end of 2003, there were only 86 thousand sheep units left in the *sum* (a decrease of 43%). The available data on livestock are presented in Table 3.

Table 3 Livestock number in Ugtaal sum.

	1999	2000	2001	2002	2003
Camel	2	9	2	4	6
Horse	8402	7858	6949	6296	5490
Cattle	7088	6758	3836	3238	2630
Sheep	38011	41358	28810	24901	19737
Goat	12712	16319	14105	14987	13357
Total	150804	151644	113174	101909	85998

Source: *Sum*'s livestock census data, 1999-2003

Note: Total is expressed in sheep units (SU): 1 sheep = 1 SU, 1 horse = 7 SU, 1 cattle/yak = 6 SU, 1 camel = 5 SU, 1 goats = 0.9 SU.

The Ugtaal *sum* has 4 areas of *otor* pastures, which covers 90.0 thousand hectares. These *otor* pastures are reserved for severe weather conditions.

The current situation of pasture use

Geographically, the territory of Ugtaal *sum* belongs to the forest steppe region south of the Khentii Mountains in the Mongolian steppe zone, and is part of the Euro-Asian steppe region. Mountain steppes prevail in this area (Unatov, 1950).

Hummock grass and forbs are scattered across the mountain meadow steppe (21.7 thousand ha or 20.3%), and root-stem grass and hummock grass dominate the arid mountain steppe (26.7 thousand ha or 27.7%). Root-stem grass, hummock grass, couch, feather grass, bunchgrass and forbs dominate the steppe (41.8 thousand ha or 39.0%) and bunch grass, forbs are found in the river steppe meadow (3.1 thousand ha or 2.9%).

Of the total pastureland, 66.1 thousand ha (62.0%) is pure pastureland, 23.0 thousand ha (32.6%) is rocky, 7.9 thousand ha (3.6%) is shrubby, 2.0 thousand ha (1.2%) is hilly, while 2.9 thousand ha (0.6%) is unsuitable for pasture.

Repeated overgrazing for long periods all year round adversely affects pasture vegetation growth and regeneration, and leads to declining carrying capacity of pastureland. The Eastern region of Ugtaal *sum* is used for winter grazing, but is now used continuously without any movement from one area to another.

Unsystematic grazing leads to a change in vegetation composition, and useful plant species for feeding are replaced with less useful ones, such as *chenopadium, artemisia* and *sedge*. For example, pastures in the areas of Sevduul and Sovduul are particularly overgrazed.

Roads affect 1.2 thousand ha of pastureland in the *sum* territory, and are another cause of pasture degradation.

Gurvansaikhan *sum* and Dundgovi *aimag*

This *sum* is located in the Gobi region. The district centre lies 331 km south of the Ulaanbaatar and the distance to the *aimag* centre is 71 km. Its 542 thousand ha consist almost entirely (99%) of pastureland.

The Gurvansaikhan *sum*'s population was 2690 as of January 2003. Gurvansaikhan is one of the most sparsely populated *sum*s in Mongolia; the population density is approximately 0.5 people per km^2 and the density of families with livestock is 12 families per 100 km^2 in 2003. According to the *sum* statistics, 36.2 per cent of families own less than 200 animals. About 64 % of households with herding livestock have less than 200 animals in their herd, and 16 % have less than 50 animals. These numbers (see Table 4) differ considerably from the numbers for Ugtaal (see Table 2).

Table 4 Household grouping by number of animal, Gurvansaikhan sum.

Statement	2000	2001	2002	2003
Population	2422	2462	2615	2690
Total number of households	615	592	629	672
Households with animal herds including herders' households	517	482	514	649
Of which by percentage:				
up to 10 heads	3.1%	2.5%	0.6%	1.5%
11-30 heads	11.4%	4.8%	5.8%	8.3%
31-50 heads	11.2%	7.1%	7.8%	6.2%
51-100 heads	28.0%	21.1%	18.1%	20.0%
101-200 heads	26.0%	29.1%	24.5%	27.7%
201-500 heads	16.1%	27.2%	34.2%	27.0%
501-999 heads	3.7%	7.3%	8.2%	8.0%
1000-1499 heads	0.5%	0.8%	0.6%	1.2%
Above 1500 heads	0.0%	0.0%	0.2%	0.0%

Source: *Sum*'s livestock census 2000-2003

As with most other *sum*s in Mongolia, the primary economic activity is livestock herding. At the end of 2003, the *sum* had 203 thousand livestock (in sheep units). The overall number of livestock in Gurvansaikhan has been increasing since 2000 (Table).

Table 5 Livestock numbers in the Gurvansaikhan sum.

	1999	2000	2001	2002	2003
Camel	1794	1465	1369	1324	1303
Horse	13475	6701	7099	7628	8321
Cattle	10157	1867	1673	2174	2862
Sheep	73275	48161	54100	58277	65731
Goat	57674	31222	41963	49724	61549
Total	289419	141695	158443	176089	203059

Source: *Sum*'s livestock census 2000-2003

Note: Total is expressed in sheep units (SU): 1 sheep = 1 SU, 1 horse = 7 SU, 1 cattle/yak = 6 SU, 1 camel = 5 SU, 1 goats = 0.9 SU.

Current pasture utilization

The territory of Gurvansaikhan is characteristic of its geographic location, which lies across both the central Khalkh's steppe and the desert steppe region district, Dornogovi. Vegetation cover is characterized by feather grass. The *sum*'s pasture yield per hectare is 210 kg in summer-autumn time, and 170 kg in the winter-spring period. Fodder resources are 114 Ktonnes in the summer-autumn, and 63.5 Ktonnes in the winter-spring period. Annual average fodder resources reach 91.0 Ktonnes. Herders permenantly stay around winter-spring camps. This leads to pasture degradation, particularly as there is a lack of pasture preservation and effective regulation measures.

The traditional 'best practice' pasture use (such as 4 seasonal rotations) has been abandoned. Herders move only twice a year, and the distance between seasonal camps has decreased. The animal pressure around the *sum* centre, water sources, animal shelters and campsites tends to exceed the carrying capacity of the pastures.

Because of a lack of regulation, the use of pastures has become unorganised and unsystematic, which has led to overgrazing and degradation.

According to a pasture survey conducted in 1992, good pastureland accounted for 37.2% (or 197 thousand ha) of the total territory, and 16 thousand ha of pasture was recorded as being overgrazed. Another survey in 2002 demonstrated that overgrazed pastures had increased by 28.2%. Overgrazed pastures are especially found to the west of the *sum* centre and in the northern area of the *sum*.

2.2 Data collected via a primary field survey

The questionnaire survey was tested in Ugtaal and Gurvansaikhan in September and November 2003. The final survey was carried out in Ugtaal from 24 December to 8 January 2004, and in Gurvansaikhan between 14 and 26 January 2004.

The purpose of the survey was to select 30 families with a herd of fewer than 200 livestock, and 30 families with more than 300 livestock, from each survey site. In addition, local government officials and other local stakeholders were interviewed. Furthermore, secondary data was gathered from the *sum* level livestock census, the so-called "A account". The data include very detailed information, going back 7 years in Ugtaal (1997-2003) and 5 years in Gurvansaikhan (1999-2003).

The following general principles were used when undertaking the semi-structured interviews:

- The team members encouraged interviewees to express herders' opinions freely and made notes during the discussion. When required, interviewees were asked not to divert too far from the issue under consideration. In many cases, the discussion went beyond the questionnaire in order to allow an interviewee to express important points;
- Custom dictates that women and young people should not dominate discussions in the presence of elderly people, and this may have to some degree influenced their participation in discussions. However, they were encouraged to actively participate;
- In addition to the selection of herders with less than 200 and more than 300 livestock, the broadest variation in terms of livestock numbers within the selected groups was sought.

In total, 85.3% of questions were answered and non-responses accounted for 14.7%. Most herders were willing to express their perceptions of the environment but they were more reserved when answering questions related to income and expenditures.

The survey in Ugtaal of Tov *aimag*

In Ugtaal, the first meeting was held in the *sum* centre with the vice governor of the *sum*, Mr. Tsagaankhuu, and followed by meetings with 3 *bag* governers. During the fieldwork, the whole territory of the Ugtaal *sum* was covered by deep snow. Average snow depth was 30 centimeters, and the team discussed ways to reach herders with the *bag* governers. Three *bag* governers very much helped to implement the survey sucessfully. They first called the nearest herders into one of the herding households to allow the team to interview the herders. In total, the team visited 11 herding households to interview 60 herding household representatives. In total, 27, 24 and 9 households were interviewed in the Asgat, Taliin Uul and Khar Chuluut *bag*s respectively.

Compared to Gurvansaikhan, Ugtaal is much better located in relation to major markets. Its primary advantage is its closeness to the capital city of Ulaanbaatar. Another advantage is that herders in Ugtaal have greater opportunities to prepare hay. The average amount of hay prepared by one household is 7 tonnes. At the time of survey, most herders had sent large flocks of animals to the *otor* pastures where snow depth was lower.

The survey in Gurvansaikhan of Dundgovi *aimag*

When organizing the final interview, the weather conditions in Gurvansaikhan were very favorable. This helped the team to select herding households more freely and conduct the survey without any difficulties. To select housholds for the survey in Gurvansaikhan, the survey team used the same principles as in Ugtaal. Prior selection was made based on the number of animals. As indicated by the survey methedology, herding households were selected from 2 different groups of 30 households each, one with less than 200 animals and the other with more than 300 animals. The survey team also discussed this household selection with the *sum* officials.

One of the bag governers, Mr. Tavaandelger, guided the survey team during the survey and provided a lot of useful information. With his support, the survey team visited all 60 herding households for interviews. The survey included representatives from all 5 *bag*s in Gurvansaikhan *sum*. The names of the *Bags* are Suugaant *bag,* Dersen-Us *bag*, Elgen *bag*, Gurvansaikhan *bag* and Chuluut *bag*.

On average, the *sum* herders migrate 5–8 times per year over distances of 4–11 km. More than 80 percent of the herders have access to water within 5 km of their camps. Because the pastures are in a relatively good condition, herders do not prepare much fodder. Nonetheless, a household prepares about 4–8 packs of hay, 20–50 kg of hand fodder and buys 1–2 sacks of bran annually.

Because of the subsistence nature of herder households, the domestic market for livestock products is very small in this *sum*. Major livestock products such as cashmere, meat and live animals are sold to traders from the *aimag* centre and Ulaanbaatar city. Herders confirmed that prices offered by local traders are usually lower than those offered by outside traders.

Poor herders in this *sum* face a difficult situation. Their demands for food and clothing are mostly met by helpful and wealthier relatives and friends in low-paid and labour-intensive activities. They may also rely on occasional welfare assistance from different sources. However, assistance from wealthy relatives and friends is not always reliable. Families who once helped their poor relatives tend to avoid doing so again if they can. Looking after animals owned by absentee herders appears to be an important livelihood option for poor herders.

The PRA and secondary data from the livestock census were gathered to gain information about two variables: herders' behaviour and herders' income

Key variables used to measure *herder behaviour* are:

- **Livestock** (sheep, goats, cattle, horses, camels) **numbers** over time;
- Specification of the numbers of male animals;
- Specification of the off-take and offspring of animals.

Herder income (or the net income from the herd) is calculated from fodder purchases, veterinary services, sales of animals and animal products. Unfortunately, own consumption of animal products by the household could not be included in the net income because the response to these questions in the survey was incomplete.

Within both the Ugtaal and Gurvansaikhan districts, 60 families were interviewed. In total, this amounted to120 interviews which then could be used in the analysis. The interviews were matched with the yearly livestock census to gain a better insight into the livestock dynamics over time.

Then, in order to estimate the game theoretic model as developed in Section 4, we derived the following variables from the herder-data at the household level:

1. The herd growth rate. This is the difference between offspring and off-take divided by the total herd size, and is used to measure the herder's strategy. This data is widely and reliably available from the regular livestock census in Mongolia. We need to keep in mind that the total herd size can also be influenced by hazards like droughts, *dzud* and diseases. These factors can be avoided by focusing on a cross

section of herders within a single year. Here we focus on an analysis of the year 2003, for which sufficient data is available;
2. With regard to the strategy of the herder, we also need a proxy for the net benefit of following that strategy. The net benefit consists of the income from sales of production minus the cost of production;
3. To estimate a game, it is useful to obtain a proxy of the herder’s ideas about the combined strategy of all other competing herders (i.e. how does a herder think other herders will behave?). A good proxy for this is the perceptions of the environmental quality of the grazing pastures. By undertaking a Principle Component Analysis on a number of collected perceptive indicators, we derived this proxy. The following questions were used:
    - What is the current condition of the pastures?
    - Have pasture conditions changed in the last ten years?
    - Do you have access to *otor* pasture?
    - Are you in favour of grazing reserves?
    - Are the grazing reserves currently functioning well?
    - Does your household have sufficient pasture to increase the herd size?

3. Data analysis

3.1 Principle Component Analysis (PCA)

In order to gain insight into the perceptions of herders with respect to i) their environment and ii) the behaviour of other herders, we carried out a Principle Component Analysis (PCA) on those survey variables that could reflect this perception. The PCA is used to reduce a number of variables to a few factors that best explain the variation in the variables. These factors can be seen as the main underlying perceptions of the respondents leading to the answers to the selected survey questions.

The selected variables are:

PCCUR: describes a herder's perception of the pasture conditions. If pasture conditions are considered poor, this could indicate that the other herders have an aggressive strategy, i.e. they are maximising their herd sizes. It may also be a reflection of herders' behaviour during the last few years. It is likely that the strategy of the previous years will be pursued in the future.

PCCHANGE: describes a herder's perception of the change in pasture conditions during the last ten years. A higher score on this variable indicates improved conditions. As with PCCUR, this variable can reflect a herder's perception of other herders’ behaviour: a deterioration of the pasture conditions can indicate a maximising strategy.

ACCOTORP: describes the access to otor pasture. The rationale used for the previous variable is applicable here as well: If otor pastures are not available this can indicate the use of an aggressive strategy by other herders.

ATTGR: describes a herder’s attitude towards grazing reserves as a risk reduction tool. If herders feel grazing reserves are necessary, this can indicate that other herders' strategies are seen as threatening.

GRCUR: describes the current functioning of grazing reserves. A positive perception of this functioning can indicate that the behaviour of other herders is not aggressive.

SUFPINC: describes a herder's assessment of possibilities to increase his herd, given access to sufficient pastures.

This PCA was carried out for the combined survey of 120 questionnaires and for the two *sum*s separately (60 questionnaires each).

The Principle Components Analysis (PCA) results in three factors for the Gurvansaikhan case and two factors for both the combined survey and the Ugtaal case. These are presented in Table .

Table 6 Principal component analysis of six environmental perception factors in the two studied districts in Mongolia.

	Combined Factors		Gurvansaikhan Factors			Ugtaal Factors	
	1	2	1	2	3	1	2
Current pasture conditions	0.029	**0.862**	**0.777**	0.162	-0.216	0.180	**0.893**
Change in pasture conditions	-0.339	**0.743**	**0.844**	-0.153	0.104	-0.372	**0.752**
Access to otor pasture	**0.832**	-0.137	-0.083	**0.834**	0.136	**0.828**	-0.104
Attitude to grazing reserves	**0.626**	0.101	0.048	-0.035	**0.919**	**0.747**	-0.148
Functioning of grazing reserves	**0.642**	-0.076	0.054	**0.832**	-0.112	**0.637**	-0.075
Sufficient pasture to increase the herd	0.367	0.445	0.355	-0.076	-0.432	**0.573**	0.235
Variance explained	30.6%	24.0%	26.1%	24.0%	16.9%	36.9%	23.1%
Number of observations	120		60			60	

The three dominating variables in the first factor of the combined survey (*'Access to otor pasture', 'Attitude to grazing reserves', 'Functioning of grazing reserves'*) are all related to risk management. A high score indicates that the herder perceives he has two options in case of (unexpected) harsh weather conditions: he can either migrate to distant *otor* pastures or can access well functioning grazing reserves (of which he holds a positive view) nearer by. We can therefore describe this factor as an **indicator of security**. In Gurvansaikhan, this factor is split into two. The actual risk management tools are dominant in the second factor, and the attitude towards one of these tools is dominating in the third. In Ugtaal, the same variables as in the combined survey dominate the first factor. But in this case, the variable '*Sufficient pasture to increase the herd'* is also dominant in the factor. This is also a component of security, matching with the explanation of the first factor of the combined dataset.

The second factor in the combined survey is also found in both the Gurvansaikhan and the Ugtaal surveys separately. A high score on this factor indicates a positive perception of the pasture conditions: current pasture conditions are good and have improved compared to ten years ago. A low score means the opposite: current conditions are poor and the pastures have deteriorated in the last ten years. This factor seems to describe the **perceived environmental conditions**. We also see this as a good proxy for a herder's perception of the behaviour of other herders, as it nicely captures the perceived collective outcome of the other herders. If there is a lot of overgrazing, the pastures will be in a poor condition and vice-versa. In the combined survey, the variable '*Sufficient pasture to increase the herd'* is almost dominating as well (and also positive, although of less importance, in both Gurvansaikhan and Ugtaal). This demonstrates how pasture conditions are perceived from the point of view of the herder and gives a proxy for herders' possibilities in terms of enlarging their herd.

3.2 Regression

In order to gain insight into the possible explanations for the differences in perception, the following model was estimated for the factors derived in the previous section:

1.

$$\text{Factor } i = \text{constant} + \beta_1\text{ISOLAT} + \beta_2\text{MOVE} + \beta_3\text{SEXS} + \beta_4\text{AVAGE}$$
$$+\beta_5\text{NRWOM} + \beta_6\text{NRFM} + \beta_7\text{INCOME} + \text{error}$$

In addition, model 1. was also estimated for an indicator of herd growth and the fraction of male adult animals in the total herd, which are defined as (in sheep units, see Table 1):

2.

Growth in herd size = (off spring – off take) / (total livestock)

3.

Fraction of male adults in herd = (number of male adult animals) / (total livestock)

Table 7 Meaning of the explanatory variables in the regression equations.

Variable	Explanation
ISOLAT	Sum of distances from summer and winter camps to the bag and sum centres (4 distances)
MOVE	Sum of distances between seasonal camps
SEXS	Sex of the interviewed person
AVAGE	Average age of the household
NRWOM	Number of women in the household
NRFM	Number of household members
INCOME	Total income in 2003 (sale of animals and animal products and other income)

Table 7 shows the meaning of the variables, which are included in the regression, while the results of the regressions are presented in Table 8 – Table 10. Statistically significant estimates are denoted by stars: *, P<0.10; **, P<0.05; ***, P<0.01.

Table 8 Regression result for the combined data set of both districts in Mongolia.

	Perception of security	Perception of environment	Growth in herd size	Fraction of male adults in herd
(Constant)	-0.409	-0.133	0.122***	0.253***
	(0.395)	(0.411)	(0.039)	(0.051)
ISOLAT	3.84E-03	1.97E-03	1.47E-04	3.99E-04
	(0.003)	(0.003)	(0.00033)	(0.00043)
MOVE	5.89E-03*	-6.00E-03*	-2.00E-04	-8.42E-04*
	(0.003)	(0.004)	(0.00034)	(0.00045)
SEXS	-0.348	0.299	1.06E-02	1.19E-02
	(0.191)	(0.199)	(0.019)	(0.025)
AVAGE	-1.13E-02	-4.59E-03	6.03E-04	-2.96^{E}-04
	(0.007)	(0.008)	(0.001)	(0.001)
NRWOM	0.24**	-6.15E-02	6.15E-03	-5.02E-03
	(0.111)	(0.115)	(0.011)	(0.014)
NRFM	-5.73E-02	5.16E-02	4.00E-03	8.72E-04
	(0.075)	(0.078)	(0.007)	(0.01)
INCOME	1.26E-07	1.97E-07**	2.05E-09	-1.20E-08
	(9.5E-08)	(9.8E-08)	(9.4E-09)	(1.2E-08)
R^2 adjusted	0.12	0.048	-0.034	-0.015

Table 9 Regression result for the district Gurvansaikhan.

	Perception of environment	Perception of security 1	Perception of security 2	Growth in herd size	Fraction of male adults in herd
(Constant)	0.283	-0.184	-0.399	0.171***	0.259***
	(0.58)	(0.497)	(0.569)	(0.052)	(0.057)
ISOLAT	-7.77E-03	3.52E-03	4.74E-03	9.16E-05	-1.54E-04
	(0.005)	(0.004)	(0.005)	(0.0001)	(0.0001)
MOVE	4.64E-03	7.74E-03	3.00E-03	-1.87E-03*	6.70E-04
	(0.011)	(0.009)	(0.01)	(0.001)	(0.001)
SEXS	0.145	-0.561*	-0.161	-1.61E-02	6.89E-02**
	(0.287)	(0.246)	(0.282)	(0.026)	(0.028)
AVAGE	-1.07E-02	-1.08E-02	-1.13E-02	8.25E-04	2.18^{E}-04
	(0.011)	(0.009)	(0.01)	(0.001)	(0.001)
NRWOM	0.106	0.531***	0.334*	1.17E-02	-2.09E-02
	(0.18)	(0.155)	(0.177)	(0.016)	(0.018)
NRFM	5.31E-02	-0.288***	-4.16E-02	-3.17E-03	6.39E-03
	(0.109)	(0.094)	(0.107)	(0.01)	(0.011)
INCOME	-2.94E-08	3.33E-07***	-9.06E-08	6.18E-09	-1.98E-08
	(1.3E-07)	(1.1E-07)	(1.3E-07)	(1.2E-08)	(1.3E-08)
R^2 adjusted	-0.004	0.261	0.034	-0.02	0.076

Table 10 Regression result for the district Ugtaal.

	Perception of security	Perception of environment	Growth in herd size	Fraction of male adults in herd
(Constant)	4.23E-02	-1.359**	8.66E-02	0.2**
	(0.658)	(0.668)	(0.067)	(0.095)
ISOLAT	1.49E-03	5.29E-03	4.48E-04	1.11E-03
	(0.006)	(0.006)	(0.001)	(0.001)
MOVE	7.80E-03	-1.51E-03	-3.81E-04	-1.08E-03
	(0.006)	(0.006)	(0.001)	(0.001)
SEXS	-0.481	0.341	3.82E-02	-4.86E-02
	(0.29)	(0.294)	(0.029)	(0.042)
AVAGE	-1.72E-02	1.56E-02	3.46E-05	-9.20E-04
	(0.012)	(0.012)	(0.001)	(0.002)
NRWOM	0.195	-8.78E-02	-1.93E-03	-6.08E-03
	(0.166)	(0.169)	(0.017)	(0.024)
NRFM	-7.35E-02	0.107	1.76E-02	7.09E-03
	(0.125)	(0.127)	(0.013)	(0.018)
INCOME	-2.95E-08	4.43E-07**	2.40E-09	1.36E-08
	(2E-07)	(2E-07)	(2E-08)	(2.9E-08)
R^2 adjusted	0.09	0.063	-0.043	-0.066

Table 8 shows that herders, who travel longer distances (MOVE) and have a higher number of female family members, have a higher perception of security (first column). In addition, herders with high incomes have a better perception of the environment. This indicates that income matters, and it also indicates that relatively poorer herders tend to assign a lower value to their environment (second column). This result is intuitive as richer herders are more powerful and possibly find it easier to secure good quality pastures, whilst poorer herders are left with pastures of lower quality. The result in the third column is insignificant, which indicates that there is no link between income and rate of herd growth. This suggests that there is no significant difference in the strategies (at least in the way of growth in animal numbers) of poor and rich herders. Therefore we cannot find evidence for our second hypotheses: that poor herders have a greater willingness to maximise their herd size. The result in the fourth column shows that a low frequency of movement explains the fraction of male adults in the herd, while the constant is also significant. All we can conclude from this is that herds with relatively large number of male adults tend to move over shorter distances.

Table 9 has five columns, as there are three factors for the case of Gurvansaikhan. The first column is fully insignificant. This means that, for the case of Gurvansaikhan, we find no explanation for the variance in perception of environmental variability. This also indicates that we have no evidence for accepting the first hypothesis on the link between environment and wealth. The second column shows the most significant result of all the regressions, even though it is hard to explain the factors underlying these correlations: Male respondents, with small families consisting of a comparatively large number of women, and who are relatively rich, correlate with a positive attitude to *otor* pastures and grazing reserves. The second indicator of security follows the same pattern and confirms the previous result for the number of women in the family (third column). The fourth column shows that herders with a lower intensity of movement tend to increase their herd size. The result of the fifth column indicates that female-headed families tend to rear herds with relatively more male adults. We cannot find any explanation for such a result.

Table 10 shows the results for Ugtaal. The first and third columns of the four regressions are totally insignificant. This means that we do not find any explanation for the perception of security and the maximizing behaviour of herders in Ugtaal. The fourth column is only explained by a trivial significant constant, which does not help much. The second column, however, presents us with an important correlation, namely that herders with a higher level of income tend to have a better perception of the pasture conditions. We had already found this result in the regression for the pooled data set. Once again, we have some evidence for the hypothesis that poorer herders face a worse environment in the district of Ugtaal.

4. Game estimation

4.1 The inter-herder game in Mongolia

Consider the following situation: It is November and winter is about to start. Imagine a delineated winter grazing area in a Mongolian region. The summer grass-growth season is over and the winter pasture is restored and ready to be grazed. Around this time herders decide on an appropriate level of herd 'off-take' and slaughter a number of their animals.

This situation can be formalised by identifying strategies and players in a game as follows: The herders are playing a game about what herd size to maintain. Their decisions have consequences, however. Principally, when herders choose to maximise their herd size, the risk of negative impacts from possible future *dzud*, droughts and diseases increases. On the other hand, when they reduce their herd size, they may not fully benefit from the (winter) grazing opportunities. Taking these considerations into account, we can demonstrate how this game works by way of a metaphorical two-person two-strategy representation.

In order to formalise possible conflicts, which can emerge between herders, we restrict the analysis to two *equal* herders $\{1,2\}$. In the case with n herders contesting for grazing pastures, we can distinguish between 'Herder 1', the challenger, and 'Herder 2', the contender. 'Herder 2' is composed of all other herders contesting for the same winter pasture. We need to assume that the challenger interprets the actions of other herders as a simultaneous move. Hence, we are dealing with a 1 versus $n-1$ persons game (see also Lise 2001; Lise et al 2001).[3]

The herders choose their herd size, which determines the survival rate of their herd and, hence, their payoff. When both herders keep their livestock constant, they obtain x; when the herders increase their livestock they obtain y; when one herder increases his/her herd and the other keeps his/her herd constant, the herd-increasing herder obtains a and the

[3] One of the earliest accounts of games among herders is the herdsman game as formulated by Muhsam (1973), which also is put in a 1 versus $n-1$ person setting.

herd-maintaining herder obtains *b*. Note that since we start our analysis from the viewpoint of a normal year, the herders know that they can have access to well-stocked pastures, even if it would not be sustainable in the longer term. Table 3 shows the resulting payoff matrix.

Table 11 Payoff matrix for the game between two symmetric herders.

		Herder 2: (contender)	
		Keep herd constant	Increase herd size
Herder 1:	Keep herd constant	x,x	b,a
(challenger)	Increase herd size	a,b	y,y

If the contender maintains his/her herd, there will be more grass left for the challenger who can feed his/her herd without purchasing additional and expensive fodder. If the contender maximises his/her herd size, it is still better for the challenger to do the same, as (s)he is not sure that when (s)he accesses the winter pasture, it will be in good grazing condition. This depends on weather conditions and possible overgrazing by other herders. Both herders, however, are better off with a mutual constant herd size. This puts them in a better position when facing a possible *dzud*, since the impact of a *dzud* will be much more severe in the case of a large herd size in the beginning of a extreme cold period. The same reasoning is true for droughts: it is much more difficult to maintain a large herd size during a drought, particularly as a smaller herd is more mobile. Following this argument, we hypothesise that the game of setting herd sizes resembles a prisoner's dilemma:

4.

$$a > x > y > b$$

Such a situation, where mutual cooperation is only possible through communication and trust (see for instance Fukuyama (1995)), is difficult to resolve. Another possible way to achieve mutual cooperation is through utility transfer. For example, Bromley (1998) provides the economic rationale for an irrigation system where head enders put an externality on tail enders. Institution building is also an option, as clear grazing rights can avoid conflicts over grazing pastures. They also provide assurance to farmers that present conservative behaviour can be rewarded by future access to greener pastures. Communication, trust, transfers and well-defined property rights are all institutional measures that change the prisoner's dilemmas into a harmonious situation.[4]

Hence, we hypothesise that herders will maximise their herd sizes because there are no well-defined grazing rights (which could justify current lower levels of grazing), even though they are fully aware that this increases their vulnerability to *dzud* risk.

4.2 Technical description of the game estimation procedure

To estimate the herder game we need to construct the triple $(\pi_i, \theta_i, \vartheta_i)$, where π_i is the payoff for household *i*, (measured as the net income from the herd), while θ_i is the strat-

[4] See for instance Ostrom (1990) and Ostrom et al (1994) for the linkage between institutions and resource management.

egy for household *i*, (measured as the growth rate of the herd), and ϑ_i is the strategy of all other herders (the contenders) as perceived by the challenger. ϑ_i can be derived from the perceived environmental conditions, which is the second factor in the PCA in Ugtaal and the first factor in Gurvansaikhan.

To interpret the value of the strategy, it is useful to normalize the strategy of the challenger θ_i and the strategy of the contender ϑ_i. In general, variable s_i can be converted into a fraction between 0 and 1 as follows:

5.

$$\tilde{x}_i = \frac{s_i - \min_{k \in N} s_k}{\max_{k \in N} s_k - \min_{k \in N} s_k} \text{ for all } i \in N$$

The households can be assigned to four clusters, so that the Euclidean distance within clusters is minimized, while the Euclidean distance between clusters is maximized.[5] The Euclidean Cluster Method (ECM) yields final cluster centres. The following Table shows how to assign the final cluster centres of the actions of the challenger (θ) and the contender (ϑ) to payoff-groups *A*, *B*, *X*, *Y*.

Table 12 Assigning households into clusters, using final cluster centres.

Choice of the herder (θ)	Choice of other herders (ϑ)	payoff group
'increase herd size'	'increase herd size'	Y
'increase herd size'	'keep herd size constant'	A
'keep herd size constant'	'increase herd size'	B
'keep herd size constant'	'keep herd size constant'	X

Alternatively, it is also possible to sort the payoffs into four payoff groups by taking 0.5 as the threshold value. We define values of θ and ϑ above 0.5 as participative behaviour, in the sense that herders try to keep their herd size constant, while values of θ and ϑ below 0.5 indicates that herders are trying the expand their herd size. We refer to this simple way of splitting the payoffs as the Simple Threshold Method (STM). Assigning the payoffs was done as before and as shown in Table 12.

Finally, the payoffs can be calculated by applying formula 6, where $|X|$ denotes the number of observations in payoff-group *X*:

6.

$$a = \frac{1}{|A|}\sum_{i \in A} \pi_i ; b = \frac{1}{|B|}\sum_{i \in B} \pi_i ; x = \frac{1}{|X|}\sum_{i \in X} \pi_i ; y = \frac{1}{|Y|}\sum_{i \in Y} \pi_i$$

4.3 Results

The estimation procedure (as explained in the previous Section) is applied to derive the herder games in Ugtaal and Gurvansaikhan. In order to obtain insight into the assignment of payoffs to payoff groups, the choices of the challenger and the contender are plotted in Figure 1 and Figure 2. The choice of the challenger, θ, represents the growth in

[5] This is possible through a standard procedure of SPSS (Norusis, 1990).

herd size; a high θ represents low growth, while a low θ represents high growth. The choice of the contender, ϑ, represents the perception of the environment; a high ϑ is a positive perception, while a low ϑ means a negative perception. Figure 1 and Figure 2 show the result in the case of both the ECM and the STM. The clusters based on the ECM are represented by diamonds, triangles, circles and squares, while the clusters based on the STM are simply the four areas delineated by the thick lines in Figure 1 and Figure 2.

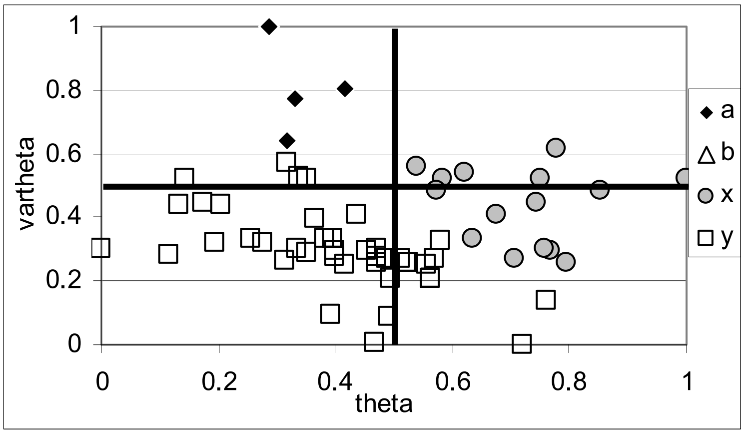

Figure 1 Scatterplot of strategies in Ugtaal.

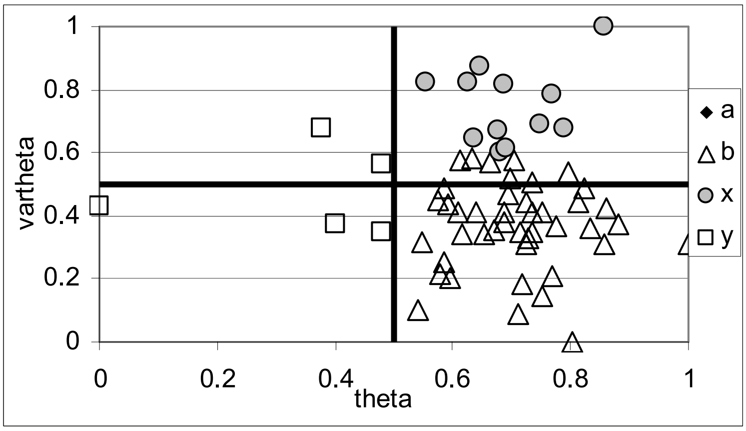

Figure 2 Scatter plot of strategies in Gurvansaikhan.

The interpretation of Figure 1 and Figure 2 already leads to an interesting finding, namely that there is more herd size maximising behaviour in Ugtaal than in Gurvansiakhan. This is shown in the figures by the concentration of data in the lower left-hand side in Ugtaal (increasing herd size, quality of the environment perceived to be low) and the right-hand side in Gurvansaikhan (more constant herd size, irrespective of perceived environmental quality).

The game estimation results (using the primary data as explained in Section 2) are presented in Table13.

As we attempt to interpret the results as presented in Table 13, the game in Ugtaal appears to be ambiguous. On the one hand, we find a prisoner's dilemma as hypothesised in equation 4. with the ECM. If this were the case, then it is equilibrium behaviour to maximise the herd size, but with the institutional viable alternative where the herders are better off reducing their herd size. Inspection of Figure 1 shows that the division of payoffs based on the ECM is a bit arbitrary. On the other hand, the STM yields a reverse assurance game. If this is an accurate representation of the current situation, then there are two equilibriums in Ugtaal; however, the maximising herd size equilibrium leads to the highest payoff. Figure 1 shows that there is a significant difference between the division of strategies using ECM and STM. The STM division seems to get closer to reality.

Table 13 The estimated herder game using primary data, when the strategy is to choose herd growth rate.

	a	b	x	Y	Payoff order	Name of the game
Ugtaal.ECM	1246.6		487.4	241.6	a>x>y>b	Prisoner's dilemma
	(4)		(15)	(41)		
Ugtaal.STM	248.1	455.3	268.9	655.0	y>b>x>a	Reverse assurance game
	(27)	(19)	(6)	(8)		
Gurvansaikhan.ECM		1017.3	967.1	1049.2	y>b>x>a	Reverse assurance game
		(43)	(12)	(5)		
Gurvansaikhan.STM	862.0	1126.9	942.8	1330.1	y>b>x>a	Reverse assurance game
	(3)	(19)	(36)	(2)		

Note: the number in the brackets denotes the number of observations within the payoff group. Payoffs are expressed in thousands of the local Mongolian currency Tugrik, which was equivalent to € 0.74 at the time of the survey.

The game in Gurvansaikhan is easier to interpret. With both division methods, the same reverse assurance game was found. The interpretation of this game is equivalent to that of the second game in Ugtaal, namely that there are two equilibriums; however, the maximising herd size equilibrium leads to the highest payoff.

Thus, there are viable institutional means to encourage herders to change their behaviour from herd maximisation (most common in Ugtaal) to keeping herd sizes constant. However, herders would need to be compensated for the loss of income incurred by keeping a small herd. If such a mechanism can be put in place, the transition to sustainable pasture management will be within reach.

This result also ties in well with the study on carrying capacity dynamics undertaken by Dietz *et al*. (2004). According to their analysis, the carrying capacity is dynamic (dependent on variation of temperature and precipitation), and has not yet been exceeded in more densely populated and relatively green district of Ugtaal, except during the *dzud* in 1998. They also claim that the dynamic carrying capacity has been exceeded in the dryer and sparsely populated district of Gurvansaikhan. That the game in Gurvansaikhan still does not show a lower payoff for maximising the herd size may indicate that the deteriorating environment has not yet led to repercussions in terms of herder income. In addition, the absolute number of herders with fast growing herds is very small (i.e. Figure 2) in Gurvansaikhan. That there is a higher payoff under herd maximisation in Ugtaal supports the claim that there is still space for increasing herd sizes there. Hence, the game based on the STM seems to be the most representative for the situation in Ugtaal, allowing us to reject the hypothesis that ‘the herder’s herd increasing game is a prisoner’s dilemma'. Rather, it is a reverse coordination game in Ugtaal and a reverse assurance game in Gurvansaikhan.

5. Conclusions

The hypotheses that guided this study were:

- The poorer the herders, the worse the quality of their pastureland;
- The poorer the herders, the greater the willingness to maximise animal numbers;
- Maximising animal numbers is optimal behaviour for herders;
- There are viable ways to change herders' behaviour towards socially optimal animal numbers;
- Herder behaviour which maximises animal numbers causes a long-term degradation of ranges, which increases poverty.

A Principle Component Analysis on the perception of herders with respect to their environment gave a mixed result. On the one hand, herders in Gurvansaikhan place the greatest importance on the environment, and have a mixed attitude to grazing security as the second and third factor. On the other hand, herders in Ugtaal value grazing security as most important issue, while their perception of the environment is only a secondary factor.

Regressions with the primary data allow us to accept the first hypothesis: that 'poorer herders perceive the quality of their environment as being lower' in the case of Ugtaal and the joined cases, while we do not find such a result in Gurvansaikhan. We do not find any evidence for the second hypothesis. On average, the herders in Ugtaal are poorer than the herders in Gurvansaikhan. Still, this difference is not statistically significant in the regressions.

The modelled games indicate that it is indeed optimal behaviour to maximise herd size. This implies that herd sizes are likely to continue to grow at their current (unsustainable) rate, in the absence of policy intervention. However, this study also finds that a change in herders' behaviour both in Ugtaal and Gurvansaikhan is perceivable. Nevertheless, this behavioural change is difficult to achieve, as it involves a move from an equilibrium with a high payoff to an equilibrium with a lower payoff. This decrease can grow to 30% in Gurvansaikhan and up to 60% in Ugtaal. Offering herders alternative income generation activities could help encourage a switch to an equilibrium with lower herd sizes. As such, this is one of the study's key policy recommendations. In conclusion, herder behaviour can be altered for the benefit of the environment, but this will only be achieved if herders are compensated for the considerable losses caused by such a policy change.

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